Development of a small-scale fire propagation test for conveyor belts

E. D. Yardley, M. Williams, S. Wymark and L. R. Stace

Because conveyor belts can constitute a fire risk in certain environments, fire resistance tests have been used for many years to provide a satisfactory level of protection. The large scale facility used in the UK to carry out fire propagation tests on conveyor belts closed at the end of September 2000, creating a need to provide an alternative means of testing. The paper describes the development of a test that can be used in the absence of the large-scale facility. Measurements were made in the facility prior to its closure and used to develop a new test, based on the Mines Safety and Health Administration (MSHA) mid-scale test gallery, that simulates performance in the large facility. Acceptance levels for the new test are proposed.

E. D. Yardley was formerly with Cerberus (Mining Acceptance Services) Ltd; M. Williams is H. M. Inspector of Mechanical Engineering in Mines, Health and Safety Executive; S. Wymark is from J. H. Fenner and Co Ltd; and L. R. Stace (for correspondence, E-mail: rod.stace@nottingham.ac.uk) is at the School of Chemical, Environmental and Mining Engineering, and the School of Civil Engineering, University of Nottingham, Nottingham, UK.

 Manuscript received 7 July 2003; accepted in final form 23 January 2004.

Keywords: Conveyor belts, fire propagation test, small-scale

INTRODUCTION

Conveyor belts are widely used in many industrial situations. Because they contain large amounts of polymeric materials, their use in certain environments – especially coal mines, but also in steel works, power stations and other enclosed areas – must be controlled to minimise the fire risk.

The fire underground at Cresswell colliery in 1950 killed 80 men. The fire propagated along an intake airway for a distance of 560 m along rubber conveyor belting that was not fire resistant. One of the recommendations of the report[1] on this fire concerned the development of fire-resistant conveyor belting.

Fires are still occurring in mines and tunnels. Over the past 8 years, the number of reported fires in all underground mines in the UK has remained fairly constant at about 12 per annum, even though the number of mines has fallen. Of the total of 99 fires, 47 occurred on conveyor installations, with the overwhelming majority of these being in coal mines. Fortunately, all of those fires were contained and none became a major conflagration. Despite various initiatives being taken by the industry in terms of maintenance, detection of fires and fire extinguishing systems, it is important that standards of fire resistance of conveyor belting are maintained to avoid these fires becoming major incidents.

Tests have been developed which belts must pass to be accepted for use in safety-critical situations. For underground mines, the fire-resistance tests are the same for all types of belts. They are contained in BS 3289:1990[2] for textile carcass belts and in British Coal Specification 730:1989[3] for steel cord belts. They comprise the Spirit Burner test, which examines resistance to ignition, the Drum Friction test, which examines the tendency of belts to start a fire under conditions of frictional heating and the High Energy Propane Burner test, which examines the resistance of conveyor belts to the propagation of fire along their length. The test gallery used in the UK to carry out the High Energy propagation test closed at the end of September 2000. Thus, while the facilities still exist for the Spirit Burner and Drum Friction tests to be made, the High Energy Propane Burner propagation test (HE test) in BS 3289:1990 and British Coal Specification 730:1989 can no longer be carried out in the UK. This paper is concerned with finding alternative means of examining the resistance of conveyor belts to fire propagation.

Four different conveyor belt fire propagation tests are currently specified in the European Union for the acceptance testing of belts for use in coal mines. A comparison exercise carried out in the early 1990s[4] revealed that belts which met the acceptance requirements in some tests failed others, and belts which performed well in certain tests burned out completely in others. It can be concluded that other tests used within Europe cannot be relied upon, therefore, to provide comparable results to the UK HE test and could not be substituted for it.

Several sections of the law are relevant to fires and underground belt conveyors.[5–8] For example, the Provision and Use of Work Equipment Regulations 1998 require employers to ensure that the exposure of persons to risks from fire or overheating be prevented or, if this is not reasonably possible, adequately

DOI 10.1179/037178404225004292

controlled. Similarly the Coal Mines (Owners Operating Rules) Regulations 1993 has a requirement within the Model Rules that the fire resistance of conveyor belts will be defined by BS 3289 for textile carcass belts or British Coal Specification 730 for steel cord belts.

Research was, therefore, sponsored by the Health and Safety Executive immediately prior to the closure of the UK test facility to seek to develop an alternative means of testing. This paper describes the work carried out which is reported fully in Health and Safety Executive Contract Research Report 407/2002 *Fire safety testing of conveyor belts*.

OBJECTIVES OF THE RESEARCH

The principal objective of the work was to develop small-scale laboratory tests that could be used to examine the behaviour of conveyor belts in the absence of the large scale facility, seeking to correlate performance in these tests with performance in the large gallery.

To achieve this objective, it was first necessary to determine how the large-scale UK test gallery responded to known fires. The data gathered for this purpose were also intended to enable a large-scale gallery to be constructed, if the need were to arise again in the future, with the same thermal characteristics for testing or forensic purposes.

A subsidiary objective was to seek to obtain some understanding of the importance of changes in test conditions on the performance of belts currently approved for use in coal mines.

LITERATURE SURVEY

A survey of the relevant literature revealed that other workers had sought to replace large scale propagation tests for conveyor belts with smaller scale facilities. Two basic approaches were evident: (i) the use of small scale tests to measure materials' fire properties coupled with flame spread theory to predict performance in the large scale tests;[9] and (ii) the use of the so-called mid-scale galleries.[10]

Neither had been completely successful. With the limited resources available to the present study, it was considered that work with mid-scale galleries offered the better prospects for achieving the objectives of the present programme.

EXPERIMENTAL WORK

The experimental work was in two parts. The first part was carried out using the former British Coal large-scale fire gallery and the second using the mid-scale Mines Safety and Health Administration (MSHA) gallery.[11] Two types of tests were carried out in each gallery – tests to characterise the gallery itself and tests to determine the performances of selected conveyor belts.

The tests in the large-scale gallery were all made prior to any work being done in the MSHA gallery. The results from the large-scale gallery were used as the basis on which to develop the mid-scale gallery test. The test conditions in the MSHA gallery were varied as the work progressed in order to try to simulate the performance of the belts in the large-scale gallery.

The closure of the large gallery left no opportunity for repeating any of the work in the event of problems, or for returning to the gallery to confirm correlations in performance.

Large-scale gallery

The former British Coal fire test gallery was 2 m wide × 2 m high × 24 m long with mineral fibreboard roof and walls and a concrete floor. Air was drawn through the gallery by a fan and passed through a fume treatment plant. The air speed could be varied by the use of appropriate dampers. A 340 mm high trestle on which a 4-m long test piece could be placed was sited 8 m from the mouth of the gallery. A symmetrical 5 × 5 array of K-type thermocouples was situated in a vertical plane across the gallery 6 m behind the leading edge of the trestle to measure the temperature of the exhaust gasses. A propane burner 450 mm square × 210 mm high was sited 50 mm inside the leading edge of the belt sample.

For the HE test described in BS 3289, the test piece is 4 m long, the air speed is 1·5 m/s, the burner is ignited for 50 min and the quantity of gas consumed in this time is 7·5 kg.

Tests in the large-scale gallery

For these tests, instrumentation additional to that required by BS 3289 was installed:

(i) An array of nine hot wire anemometers positioned 0·75 m in front of the trestle, to determine the distribution of air velocities across the gallery section at various nominal air velocities both before and during fires.

(ii) A sampling probe sited in the centre of the exhaust duct and leading to an oxygen analyser.

(iii) A differential pressure transducer sited at the same position as the oxygen probe.

If the air velocity is known, the measurement of the exhaust air temperature in the HE test gives a measure of the power of a fire (heat release), as does oxygen depletion. The oxygen and differential pressure probes in the exhaust duct were intended to provide a second means of calculating the power of the fires.

Tests were made at nominal air velocities of 0·5, 1·5 and 2·0 m/s using known heat inputs with two propane burners complying with BS 3289 and no belt present to simulate a fire occurring when a conveyor belt sample is burned. The input power of the fires was known from the quantity of propane consumed.

For all of the tests in the large gallery, the nominal velocity was set using a portable anemometer inserted through a port in the side of the gallery.

Due to the limited time available, it was only possible to carry out tests on three types of conveyor belt. These were chosen to give different amounts of propagation: (i) a belt that would readily pass the High Energy Propane Burner test in BS 3289 (Belt A); (ii) a belt that would give an intermediate amount of

Table 1 Details of belts tested

Code	Construction	Thickness (mm)
A	Solid woven PPe 1750 N/mm PVC impregnated 1/1 PVC covers 15·2 kg/mm2	12·5
B	Solid woven EePe 490 N/mm rubber impregnated 4/1·5 rubber covers 9·8 kg/mm2	8·5
C	Solid woven EbPe 875 N/mm PVC impregnated 2/2 rubber covers on 1/1 PVC 16·5 kg/mm2	14

1 Arrangement of thermocouples attached to belt

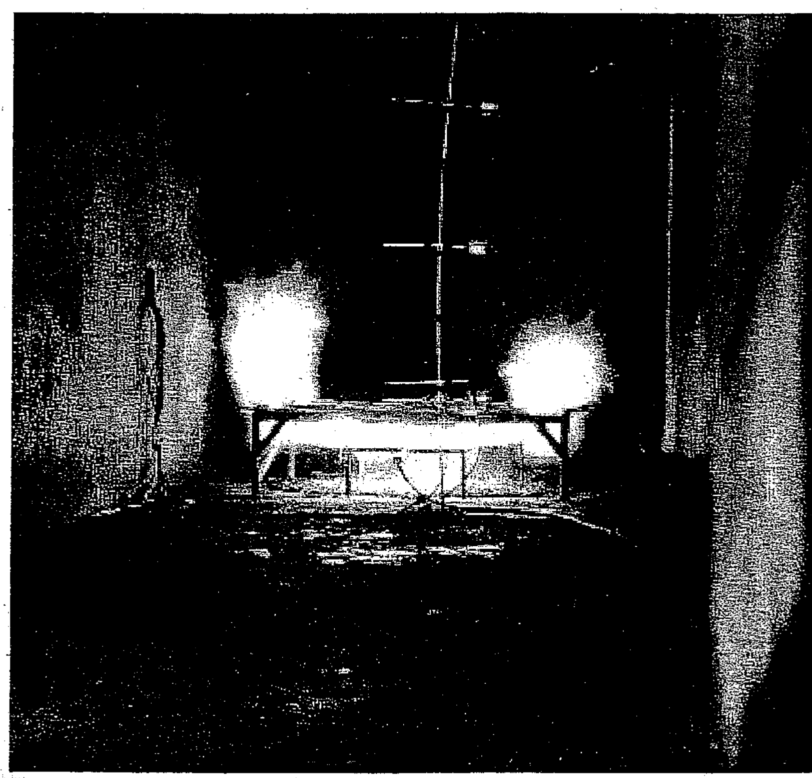
propagation and be 'marginal' in BS 3289 (Belt B); and (iii) a belt that would give extensive propagation and be expected to fail BS 3289 (Belt C). Table 1 gives details of these belts; all were 1050 mm wide.

For these tests, 15 K-type thermocouples were attached to the surface of each belt sample in order to record the progress of the fire down the belt. They were positioned basically in two rows starting just at the end of the area of the influence of the burner flames as shown in Fig. 1.

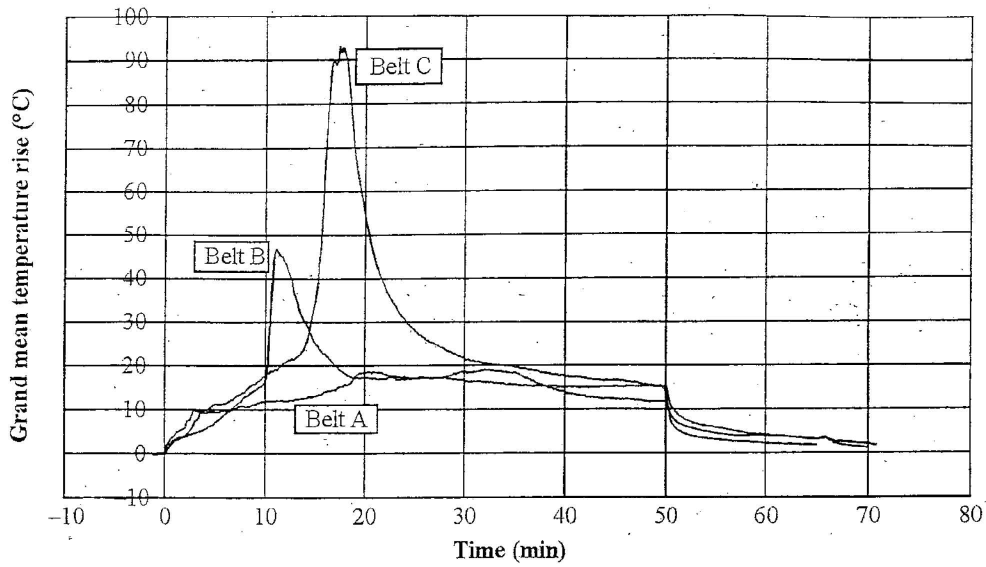
Replicate tests were made with each of the three belts at a nominal air velocity of 1·5 m/s. In addition, replicate tests were made with Belt A at nominal air velocities of 1·0 and 2·0 m/s. All of these tests were made to the methodology of BS 3289, with the requisite measures of damage to the belt samples and air temperature rise being made. Fig. 2 shows the start of a test on Belt C. Due to a fault in the gas flow control equipment, the quantity of gas used for the belt tests was approximately 5·5 kg rather than the 7·5 kg specified in BS 3289.

Results of tests in large-scale gallery

The tests without belt present quantified the air distributions and the rates of temperature rise under various heat inputs, providing information that would allow the characteristics of the gallery to be reproduced. The air temperature rise determinations



2 Test on Belt C in large-scale gallery



3 Air temperature rise versus time for Belts A, B and C in large-scale gallery

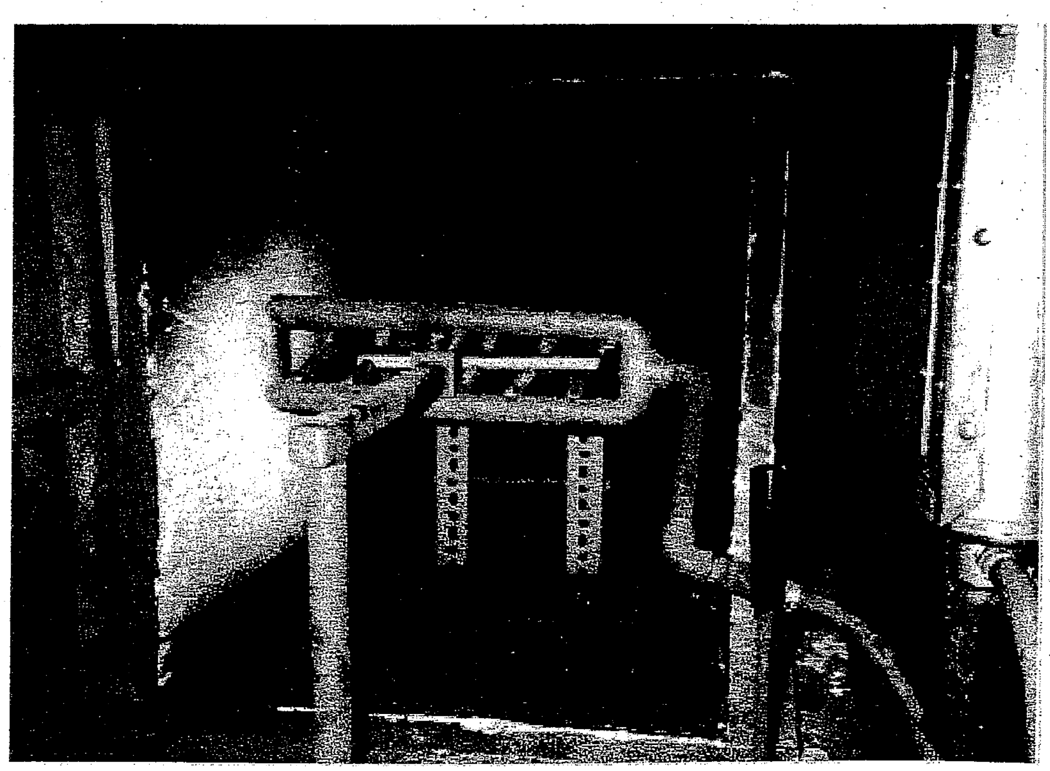
showed that even after 50 min the air temperature was still rising showing that the gallery had not reached equilibrium.

From the tests on conveyor belts, measures of performance of the three belts, including extent of damage, temperature profiles along the belt samples and flame front velocities were obtained. At an air velocity of 1·5 m/s, Belt A gave a small amount of propagation and Belt B somewhat more with a higher rise in air temperature. With Belt C, the fire propagated along the cover almost to the end of the test piece, although a much greater length of the carcass remained intact. Fig. 3 shows typical plots of mean air temperature rise against time for the three belts, indicating how they differed in the powers that the fires generated.

The tests on samples of Belt A at different air velocities allowed the effect of velocity on the extent of damage to be examined. Plotting the maximum length of belt damaged against velocity showed that there was a clear upward trend of maximum length damaged with increasing air velocity. Over the range 1·0–2·24 m/s, the length damaged increased from 1300 mm to 2000 mm.

Mid-scale gallery

The MSHA mid-scale gallery is 1675 mm long × 457 mm square in section and was constructed from 25 mm thick refractory material. The square section was connected to a 300 mm diameter exhaust duct by a conical transition section. Air was drawn through the



4 MSHA burner, trestle and test piece

gallery by a fan positioned in the exhaust duct and the air velocity was controlled by dampers. The belt sample specified by MSHA is 1524 mm long × 228·6 mm wide and is secured to a trestle made from slotted angle iron by cotter pins inserted through the belt and into the trestle at intervals along its length. The top of the trestle is 200 mm below the roof of the gallery. The burner has 12 jets arranged in two parallel rows and the sample and burner are arranged so that the belt sits mid-way between the two rows of six jets such that the flames impinge on the end of the sample. Fig. 4 shows the arrangement. Under the standard MSHA test conditions, the burner, which consumes methane at 0·567 l/s, is lit for five min. The air velocity is set at 1·02 m/s.

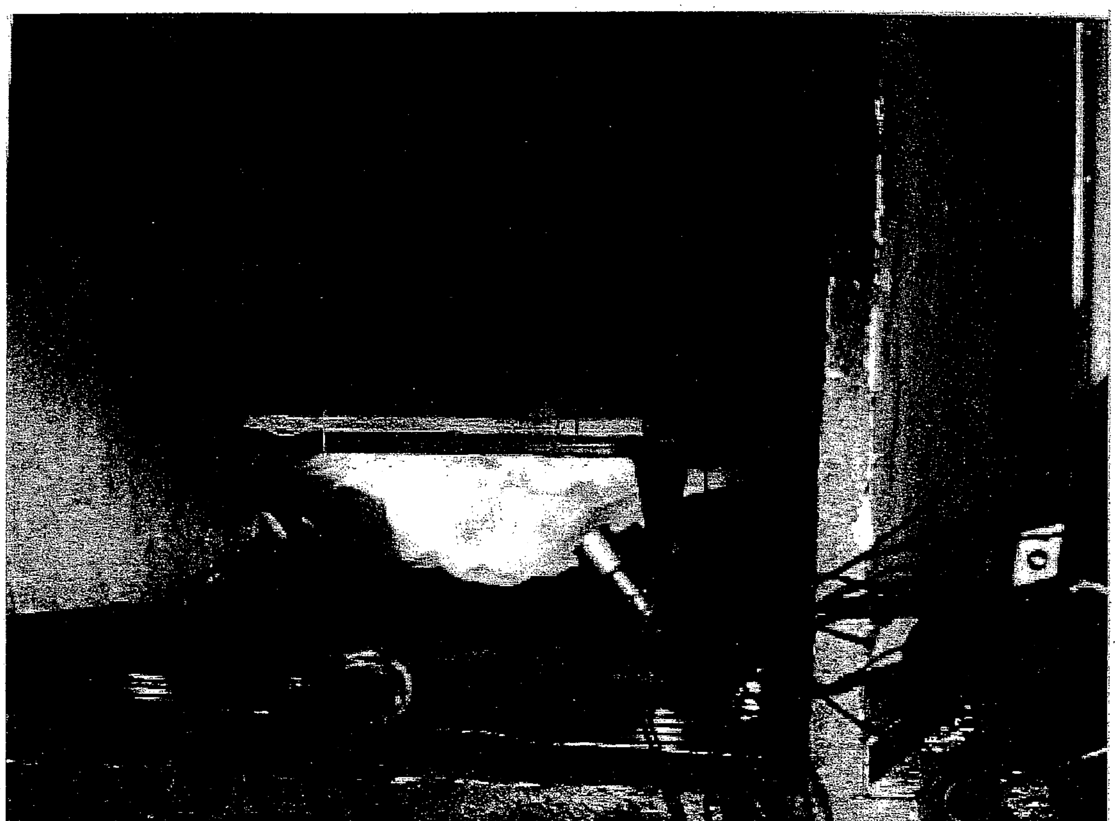
For the tests in the MSHA gallery, additional instrumentation similar to that used in the large-scale gallery was fitted. A 3 × 3 array of K-type thermocouples was fitted at the end of the gallery beyond the trestle and a similar thermocouple was positioned in the exhaust duct downstream of the air velocity control damper. A probe to allow the measurement of oxygen depletion was placed alongside the thermocouple in the exhaust duct. For the tests involving conveyor belts, 14 K-type thermocouples were attached to the belt surface at 100 mm intervals with the first one at 200 mm behind the leading edge of the test piece. This instrumentation allowed the relative severities of the MSHA and large scale tests to be assessed.

Tests in the mid-scale gallery

Tests were initially made with no belt present and only the burner ignited using both methane and propane as the fuel at a variety of flow rates and air velocities.

The results showed that the mid-scale gallery stabilised after about 10 min but, at the standard MSHA conditions, the air temperature rise was in the region of 80°C, compared to about 14°C under the standard conditions in the large gallery. At 1·0 m/s air velocity, the power of the fires calculated from the duct thermocouple temperature was closer to that derived from gas consumption than those derived from the 3 × 3 array and was a good measure of gas power. The power calculated from oxygen depletion measurements was also a good measure of gas power. At other air velocities, the agreement between powers calculated from either temperature rise or oxygen depletion with gas power was not as good as at 1·0 m/s. Insufficient time was available to investigate this matter further and it was decided that further testing would be made only at 1·0 m/s.

For the first tests with belt present, the burner was left on until either the belt in the vicinity of the burner had burned away and the belt had self-extinguished or the fire had propagated along the test piece. This decision was made to comply with the logic in BS 3289 where the 50 min burn is designed to be more than adequate to ensure full ignition of the sample In three tests on Belt A, two at the standard MSHA conditions (equivalent to a heat input of 20·3 kW) and one with propane gas at 26·4 kW, the fires propagated rapidly down the whole length of the samples. In the first two tests, the burner was extinguished after 8 and 13 min, respectively, and in the third after 5 min. A test with Belt B using propane at 26·4 kW had to be terminated after 7 min.



5 New burner, trestle and test piece arrangement

Further tests were made, all using propane, at heat inputs between 2·6 kW and 9·1 kW without belt present and with various burner modifications involving blanking-off of some of the burner jets and using a Franke burner (similar to a Bunsen burner but larger) instead of the MSHA burner.

On the basis of the temperature rises recorded in these tests, a test on Belt A was made at a heat input of 9·1 kW. The belt self extinguished after 24 min, leaving a length undamaged of 835 mm. Using the same arrangement, Belt B burned away rapidly from the burner and self extinguished leaving a length undamaged of 1210 mm. Thus Belt B had performed better than Belt A, which was the reverse of the situation in the large gallery. Changes to the test arrangement were considered necessary to reproduce the situation in the large gallery.

The test arrangement was redesigned to position the burner underneath the sample, as in the large gallery, and the trestle was also replaced by one which would not protect so much of the belt sample from the heat input. The sample was also re-positioned to be further from the roof of the gallery to reduce the heat fed back to the unburned belt.

Tests with redesigned burner and trestle

The new burner consisted of two rows of three Type 373/1 Segas jets inclined at 45° mounted on a suitable framework to position them beneath the belt sample. The trestle was 1500 mm long × 220 mm wide × 150 mm high, positioning the top of the trestle 300 mm below the roof of the gallery. It was made from 10 mm mild steel and contained appropriate cross members at intervals to support the sample. Fig. 5 shows the new test arrangement. At this point in the programme, the test sample size was 'metricated' at 230 mm wide × 1500 mm long.

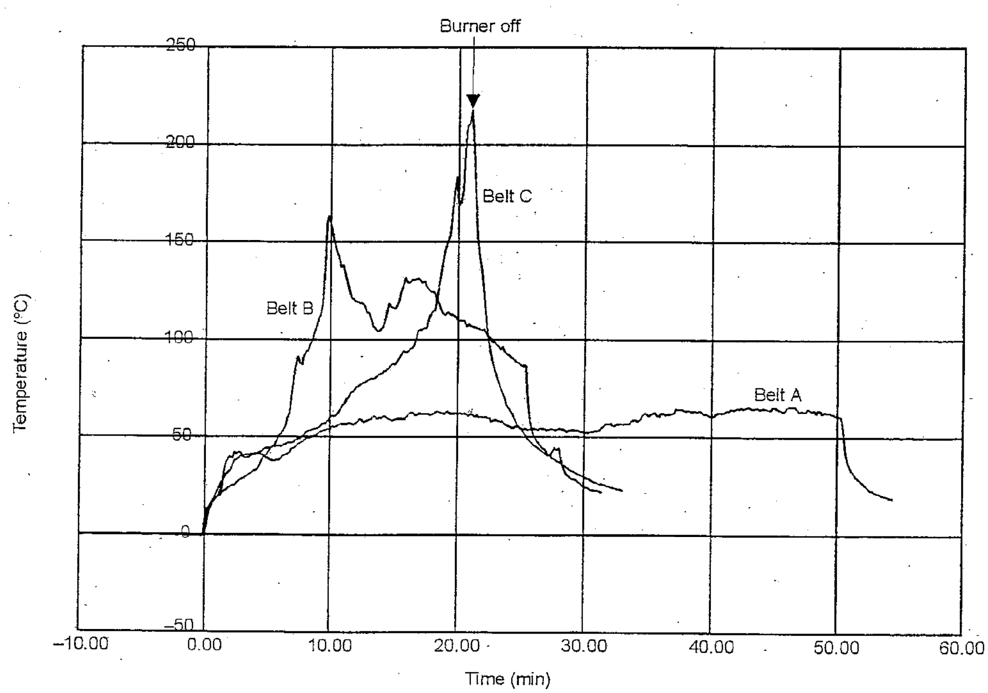
The new trestle was placed so that its trailing edge was 150 mm inside the gallery entrance and, for the first test with Belt A, the burner was 180 mm inside the entrance. The belt sample was restrained by wiring down at the front end only. With a heat input of 9 kW, the belt had to be extinguished after 42 min for reasons of safety. The sample had initially deflected upwards from the trestle, returned back to the trestle after 20 min and began to burn visibly after 33 min. The instrumentation showed that the intensity of the fire and the speed of its progress down the belt had increased rapidly after 39 min.

The reason for the rapid progress of the fire was considered to be associated with the deflection of the belt upwards from the trestle when heat from the burner was being directed less towards the belt and more into the cabinet and the air. This, in turn, resulted in the temperature of the belt downstream being closer to the ignition temperature and a more rapid spread of the fire along the belt.

A second test was made at 9 kW on Belt A with additional restraint, wiring down the belt at the centre and rear and with the trestle 150 mm inside the gallery. The burner was raised from the floor by 25 mm and was positioned so that the first jet was in line with the front edge of the belt sample. The belt ignited and self-extinguished, leaving 900 mm undamaged on the top surface and 850 mm on the bottom. The length destroyed (measured by weight) was 285 mm, showing that the belt had burned only a short distance beyond the influence of the burner, which was estimated to be 250 mm.

Belt B was tested under the same conditions, except that the centre wiring was moved to 300 mm from the front. The belt burned with increasing intensity before dying back and going out. The lengths undamaged were 550 mm top and 540 mm bottom, with the length destroyed being 770 mm, indicating substantial propagation beyond the burner.

Testing Belt C under the same conditions as Belt A resulted in a progressively increasing fire such that



6 Air temperature rise versus time for Belts A, B and C in revised MSHA gallery

after 20 min the burner had to be turned off and the fire extinguished for reasons of safety. The cover had burned away completely but a substantial length of the carcass was still intact.

The revised test conditions, therefore, reproduced both the rank order and the manner of burning of the belts in the large scale test. Fig. 6 shows a plot of the air temperature measured in the duct against time for the three belts. The similarity with Fig. 3 is striking.

Further tests were made with the new test arrangement, using Belt A, to explore the effect of varying some of the test parameters. The gas flow rate, the height of the burner relative to the belt and the degree of restraint of the belt were changed separately. In tests at heat inputs between 5·2 kW and 17·2 kW, the maximum length damaged varied between 500 mm and 820 mm. The relationship was almost perfectly linear. The other changes had little effect on the length damaged.

Repeatability and confirmatory tests

Repeat tests were made on the three belt types at 9 kW, with the burner raised 25 mm and with the samples fully restrained to the trestle. Repeatability was good, with very clear distinction between the performance of the three belts.

At this point in the project, it was considered that the new test arrangement was a good simulation of the large gallery in terms of belt performance and a series of tests was undertaken to determine the performance of other belt types. The range of belts tested was chosen to:

(i) Encompass the complete range of belts currently accepted for use in UK coal mines using the High Energy test, including the top and bottom of the strength range for both textile carcass and steel cord belts and a cable belt.

(ii) Examine the performance of a belt that was not fire resistant.

(iii) Examine the performance of a belt that would have not have passed the 50-min High Energy test but had passed a test using the same geometry but a 10 min burn.

(iv) Examine whether the test was sensitive to changes in cover chemistry.

These test showed that:

(i) All of the belts selected to represent the range approved for use underground performed well, with none recording a length damaged of more than 650 mm.

(ii) The belt that was not fire resistant caught fire rapidly and had to be extinguished after 5 min.

(iii) The belt that had passed the 10-min burn started to burn rapidly after 14 min.

(iv) The test is able to distinguish between different qualities of cover on the same carcass.

From these results, it was concluded that the new test could be used to simulate performance of belts in the large scale gallery.

Acceptance requirements

Meeting any one of the following acceptance criteria in the HE test results in a pass either: (i) 2250 mm left undamaged; or (ii) maximum average temperature rise not exceeding 90°C, length consumed by weight not exceeding 2000 mm and 250 mm undamaged; or (iii) maximum average temperature rise of 80°C, length consumed by weight not exceeding 2250 mm and 250 mm undamaged.

It is useful to consider the origin of these criteria before discussing the setting of acceptance requirements for the new test.

Derivation of acceptance criteria for High Energy test

The HE test was developed from the original 'Luxembourg' test which had a 2 m test piece and a 10 min burn. The pass criterion in the British Coal version of this test was that 250 mm should remain undamaged at the end of the test. The figure of 250 mm has no greater scientific significance than representing a measurable piece of belt at the end of the test piece. The extension of the test piece length in the HE test to 4 m makes the length undamaged 2250 mm (criterion [i] above).

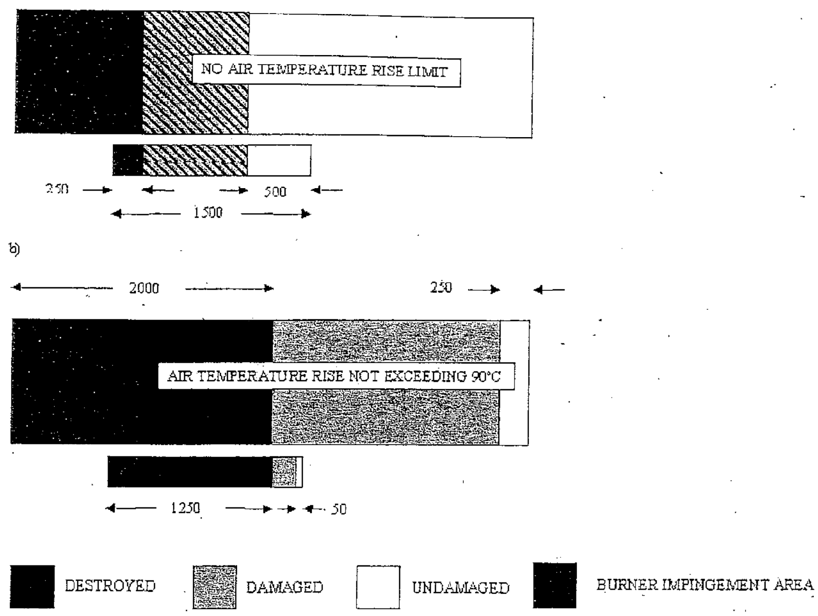
Assessment of performance in the HE test was initially based on subjective observations of the intensities of fires, but this was gradually replaced by objective measures, the air temperature rise, which gives a measure of the intensity of the fire, and the length consumed. It was considered that the definition of damage in the 'Luxembourg' test overestimated the true extent of propagation, which was better defined by combustion damage which completely penetrated the belt. The length consumed by weight was thus derived. The original proposal[12] for acceptance criteria for the HE test related to criteria (ii) and (iii) only and did not include the length undamaged requirement of 250 mm in (ii) and (iii).

The values in criteria (ii) and (iii) represent particular limits that were initially considered, subjectively, to be acceptable. They cover belt fires with higher intensity, short duration (90°C, 2000 mm) and lower intensity, longer duration (80°C, 2250 mm). The inclusion of a length undamaged of 250 mm in criteria (ii) and (iii) limits propagation of the fire along the belt cover, as with Belt C in this work .A length of damage of 3750 mm is, therefore, allowed. This length is dependent completely on the chosen length of the test piece.

Derivation of acceptance criteria for new test

A pragmatic approach had to be taken to setting proposed acceptance criteria for the new test.

With test piece lengths of 4000 mm in the HE test and 1500 mm in the new test, it is not possible to match the length requirements directly. However, since the duration of the tests are such that it is intended that the piece of belt over the burner is to be destroyed, what is important is the length of propagation beyond the region of influence of the burner. The burner influence was considered to extend to 1000 mm in the HE test and 250 mm in the new test. If the test pieces are arranged as in Fig. 7 with the ends of the burner influence lined up, some of the length requirements in the HE test can be accommodated on the new test piece.



7 Setting acceptance requirements for new test

Thus for criterion (i) the length undamaged of 2250 mm is seen to be equivalent to 500 mm in the new test and the length consumed of 2000 mm in criterion (ii) becomes 1250 mm in the new test. However, the length consumed of 2250 mm in criterion (iii) falls at the end of the new test piece and for both criteria (ii) and (iii) the length undamaged of 250 mm falls well beyond the end of the new test piece.. However, it was considered that there should be some length of belt remaining undamaged and a figure of 50 mm was suggested for criterion (ii): criterion (iii) would have no equivalent.

To relate the allowable maximum average temperature rise in BC 158 with that in the new test, differences in volumetric air flow and fuel consumed must be considered. In terms of these parameters, temperature rises in the mid-scale gallery should be about 3 times those in the large gallery, giving temperature rises of 270°C and 240°C as equivalent to 90°C and 80°C, respectively. However, the limited experience available suggested that temperatures above 170°C resulted in complete destruction of the sample, Thus, in the restricted environment of the mid-scale gallery, a maximum allowable temperature rise of 170°C, or somewhat below it, would be more practical. This limit represents a significant tightening of the maximum heat release rate requirement.

Following inspection of the results, it was considered that criterion (i) could be tightened to 600 mm. Similarly, it was considered that the temperature rise figure for criterion (ii) could be reduced to a level such that one of the chosen belts, Belt B, would be a marginal failure. The following agreed acceptance criteria were proposed: either (i) > 600 mm of belt undamaged with no maximum temperature requirement; or II) > 50 mm left undamaged, maximum temperature rise in the duct of 140°C and a maximum length consumed by weight of 1250 mm.

Two runs to be made on each belt type if covers are of equal thickness and 3 runs if they are not, with the third run being a repeat of the worse of the first two.

Comment on new acceptance criteria
It is accepted by the authors that the derivation of the new acceptance criteria is not scientifically rigorous and that assumptions have been made that have not been justified experimentally. Principal among these assumptions is that the tests in the large- and mid-scale galleries give the same extent of propagation beyond the burners. Ideally, the new test would have been developed using the original belts used to set the criteria for the HE test. However, neither those belts nor the test data from them were available. While it would have been more rigorous to set limits based on actual figures for temperature rise and propagation in the new test of those belts tested here that had passed the HE test, this would have lead to very restrictive criteria because of the relatively small numbers of belts tested in the current programme. This programme was conducted over a period of less that 12 months, during which it was possible to make 16 tests in the large scale gallery and 74 in the MSHA gallery. The original work to set the criteria for the HE test was made over several years with many more belts tested and much more data available. The present work has, however, shown that the new test produces the same burning behaviour as the HE test and distinguishes readily between belts with different burning behaviour (Belts A, B and C) and between belts that pass the HE test and those that do not. The criteria are based on this distinction in performance between belts which are known to be acceptable via the HE test and ones which are not. The setting of the limit for length undamaged in criterion (ii) in the new test at 50 mm is no more (and no less) arbitrary than was the limit of 250 mm undamaged in criteria (ii) and (iii) for the HE test.

DISCUSSION

The modifications that were made progressively to the MSHA set up resulted in a test that appears to correlate well with the large-scale test. However, the lack of extensive sets of data or previous results on a wide range of belts prevented a more detailed and truly quantitative correlation being established. Time constraints prevented the further exploration of the effect of heat input rate and the distance of the burner below the sample, which also affects the actual heat input to the belt. However, from the success of the correlation achieved in the test programme, it appears that belt performance is not very sensitive to heat input rate as long as the surface temperatures down the sample remain similar to those in the large-scale test.

Whilst the brevity of the test programme limited the extent to which test conditions could be varied, there was sufficient variation in the test programme carried out for a number of useful observations to be made:

(i) Increasing air velocity in the large scale gallery caused increasing damage to the belt sample for the same heat input and set up geometry.

(ii) The extent of propagation is not very sensitive to the rate of heat input in the large gallery or the ~~mid-scale~~ gallery.

(iii) Changes to the burner geometry and the degree of restraint of the belt sample appear to be significant. The performance of belts is much more sensitive to the way in which the heat attacks the belt than the magnitude of the heat input.

(iv) The fact that it is possible to get the 'wrong' answer in terms of belt performance by changing burner geometry is important in terms of relating performance in laboratory tests to performance in service. The burner situated beneath the belt is a better simulation of a typical belt fire underground due to a failed idler than is the original MSHA burner geometry.

The approach taken in this study has been to seek to reproduce in a smaller scale facility certain critical test parameters derived from the large-scale test. Further work on the effect of heat input rate, burner stand-off distance and air velocity would have been useful to quantify more precisely their effect on the extent of propagation. However, time pressures did not permit this to be done. The influence of burner geometry in particular deserves further study and it might be possible, by varying test parameters to identify critical circumstances in which uncontrolled propagation would take place ~~on a belt~~. Thus the test facility could be used to some extent as a predictive tool.

CONCLUSIONS

The work described here satisfactorily achieved the first of the objectives by characterising the large scale gallery in terms of: (i) air velocity distributions across the gallery cross section at three air speeds; (ii) the relationship between the mean air velocity and the differential pressure in the exhaust duct; (iii) the response of the gallery to known heat inputs; and (iv) the performance of three different types of conveyor belt.

The work identified, characterised and developed a small scale test based on the MSHA mid-scale gallery, that adequately simulates the performance of the large scale gallery.

A new test method has been provided, together with drawings of the apparatus needed and proposed acceptance levels.

The work done has provided important insights into the factors that affect fire propagation on conveyor belts, the most important of which appears to be that changes to the burner/belt geometry relationship can cause significant changes in propagation performance because of changes in the heat distributions.

ACKNOWLEDGEMENTS

This work was carried out under contract to the Health and Safety Executive. The authors would like to thank the Health and Safety Executive for financial support and for permission to publish this paper, which is based on a presentation at the Mining and Quarrying Symposium held at BGS, Keyworth, UK on 10–11 April 2002. All of the testing in the mid-scale gallery was carried out by J. H. Fenner & Co Ltd as a contribution in kind to the work. Their support is gratefully acknowledged.

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Authors

David Yardley graduated in metallurgy at the Victoria University of Manchester in 1963 and obtained his PhD 1966. He worked briefly for the English Electric Company before moving to British Coal's Mining Research and Development Establishment to work in the Metallurgy and Materials Branch. He moved up to Group Head and then Head of Metallurgy and Materials and later headed all of the testing functions, which included metallic and non-metallic materials, fire resistance and machinery testing. He moved to Eastwood Hall as part of a unit involved in the implementation of British Coal's engineering policy in 1990. He left British Coal in 1994 to set up a small consultancy. His early work for British Coal concerned the use of fire-resistant hydraulic fluids in mining machinery and later he was involved in pioneering the use of wear debris analysis for monitoring the condition of mining equipment. In the latter part of his career he became heavily involved in fire testing, particularly of conveyor belting. He served on a variety of CEN committees including conveyor belting and fire-resistant hydraulic fluids. He retired at the end of 2002.

Stephen Wymark is Development Manager – Polymers & Splicing at Fenner Dunlop Conveyor Belting (Europe) Ltd. He joined Fenner, now Fenner Dunlop Conveyor Belting, in 1977 gaining experience in a number of disciplines with regards to conveyor belting manufacture and development. This has involved extensive travel to conveyor installations and other Fenner manufacturing units worldwide to carry out training and commissioning. Main current areas of involvement are the development of rubber & PVC compounds and jointing (splicing) methods used in conveyor belting.

Mansel Williams started as a Mechanical Engineering Apprentice in a large engineering establishment and completed apprenticeship with the NCB in South Wales Area. During this period progressed academically to obtain a BSc Degree in Mechanical Engineering. Following several posts he became Unit Mechanical Engineer at Cynheidre Mine before joining the HSE Mines Inspectorate in 1983. Following service in Derbyshire, Nottinghamshire and Yorkshire he moved to the Headquarters of the Mines Inspectorate in 1995 and is a Chartered Engineer, FIMMM and Corporate Member of I.Mech Eng.

Rod Stace is a graduate of Nottingham and Newcastle-upon-Tyne Universities. Since 1995, a lecturer in mining engineering and engineering management subjects in the Schools of Chemical, Environmental and Mining Engineering, and since 2003, the School of Civil Engineering, at the University of Nottingham. Worked within the HQ Technical functions of British Coal at Doncaster, Bretby and Eastwood Hall from 1974–1995, dealing with issues surrounding the introduction and acceptance of new mining techniques and equipment.